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NEW GENERATION GROUNDBREAKING TECHNOLOGY: ORGANIC SUPERCONDUCTORS

Muhammed Selman EREL[1,*,+], Meryem Sena AKKUS[1]
[1]Ankara Yıldırım Beyazıt University, Central Research Laboratory Application and Research Center, 06100, Keçiören, Ankara, Turkey
*mselmanerel@gmail.com, msakkus@ybu.edu.tr

Abstract

As technology develops it becomes the main objective for science to find locomotive, competitive and environment-friendly methods. Superconductors are one of such technologies. These materials have many unusual electromagnetic properties, magnetic field vs. temperature relations. At the beginning, inorganic metals and alloys are utilized with the discovery of superconductors. The critical temperature of these materials has become the main obstacle that should be exceeded. As researchers are doing their best to find a suitable material to reach critical temperatures at room-temperatures they have noticed that organic superconductor materials will help them to find room temperature critical temperature material thanks to the flexible and customizable system of them. The attitude to find a proper material spins off as environment-friendly materials. As technology develops many technological products are produced. It is rather possible to see a disastrous day that nature will be polluted irreversibly and the life of each creature will be in danger. At this point, organic materials come to help nature to recycle. Environment-friendly structure of organic materials will hank- shake with nature and join them smoothly. Organic superconductors will care about nature while superconductors are seen in applications of medical instrumentation, transportation, energy storage, power generation systems. In this study, information about the history, development, and types of superconductors is given.

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Besides, organic materials with high technological importance and potential superconductivity are discussed.

Keywords: Superconductor, Organic Superconductor, Organic Material, Electromagnetism, Magnetism

YENİ NESİL ÇIĞIR AÇAN TEKNOLOJİ: ORGANİK SÜPERİLETKENLER

Özet

Bilimin ana hedefi teknolojinin gelişmesiyle öncü, rekabetçi, insanlığın refah seviyesini arttırmakta yardımcı ve çevre dostu yöntemleri bulmaktır. Süperiletkenler bu tür faydalı teknolojilerden bir tanesidir. Süperiletken olarak kullanılabilen materyaller sıra dışı elektromanyetik özellikleri ve kendisine özgün manyetik alan - sıcaklık ilişkisine sahiptir. Süperiletkenlerin keşfiyle ilk olarak inorganik metal ve alaşımları bazlı malzemeler kullanılmaya başlanmıştır. Ancak bu malzemelerin uygulamalardaki kritik sıcaklıkları, aşılması gereken en büyük engel olmuştur. Süperiletken malzemelerin metallere alternatif olarak yapılan çalışmaların sonucunda bazı organik malzemelerin istenen özelliklere sahip oldukları tespit edilmiştir. Bu tür malzemelerin kritik sıcaklıklarının düşük olması, oda sıcaklığında çalışılabilme imkânının sunulması, uygulama alanlarında çevreye zarar vermemesi gibi özelliklerinden dolayı araştırmacıların dikkatlerini üzerine çekmiştir. Bu alanda yapılan yeni organik malzemelerin sentezi ve uygulama alanlarının araştırmalarının sayısı gün geçtikçe artmaktadır. Sentezlenen yeni nesil organik süperiletkenler, başta tıbbi cihazlarda, ulaşımda, enerji depolamada, güç üretim sistemleri gibi birçok farklı alanda kullanılmaktadır. Bu durum organik süperiletken malzemelerin çevre dostu olmasından dolayı farklı kullanım alanlarında oluşabilecek direk veya dolaylı olarak çevreyi etkileyen birçok zararlı etkenin de ortadan kalkmasını mümkün kılmaktadır. Yapılan bu çalışmada manyetizmanın ve süperiletkenlerin tarihini, süperiletkenlerin gelişimini, süperiletken olarak kullanılabilen malzemeler ve özellikleri ile birlikte süperiletken tipleri hakkında bilgi verilmiştir. Ayrıca, yüksek teknolojik öneme ve potansiyele sahip süperiletkenler de tartışılmıştır.

Anahtar Kelimeler: Süperiletken, Organik Süperiletken, Organik Malzemeler, Elektromanyetizma, Manyetizma

1. Introduction

Throughout the human-being, magnetism has become one of the most fascinating phenomena. History of magnetism dates back to 600 B.C. However, scientists were aware but unable to analyze it up to the 17th century. In the 1600s, Dr. William Gilbert has published the first systematic experiment on magnetism [1]. After Dr. Gilbert, many scientific developments have happened from the production of magnet to the relation between electricity and magnetism, from electromagnets to ferromagnetic theory [2].

Magnetic fields are everywhere from Earth's magnetic field which surrounds us to tiny magnets on refrigerators, from huge magnitudes in magnetic resonance devices to rather weak values in any electronic circuits, from rotating motors to the music playing loudspeakers. They play a vital role in many fields like medical imaging to telecommunication. The generation of these fields seen in many fields is one of the hottest topics in today's science. Microscopically, these fields can be generated by moving an electrically charged particle. Macroscopically, they can be generated by sending a current through a wire. All Amperes Law, Biot-Sawart Law and Maxwell Equations give an analytical explanation about the generation of magnetic fields [3].

The aim of this study is to give a comprehensive, bottom to top, powerful, contemporary and easy-to-read review about organic superconductors. The other reviews about organic superconductors in literature are inadequate, weak, difficult-to-read, need to have high profession and confusing. Readers of this review will be highly-motivated about applications of superconductors and organic superconductor itself. They are encouraged by Organic Chemistry to explore room-temperature critical temperature superconductors.

2. Method

Ampere's Law that gives Magnetic field generated away from a distance "r" due to a current carrying wire is given below [3].

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 I \tag{1}$$

$$B \oint \vec{dl} = \mu_0 I \tag{2}$$

$$B = \frac{\mu_0 I}{2\pi r} \tag{3}$$

Table 1. Ampere's Law Definition Table

Variable Symbol	**Variable Definition**	**Variable Unit**
B	Magnetic Field	T
μ_0	Permeability	$m \cdot T/A$
I	Current	A
r	Observation Distance	m

While Eq (3) is being considered, If 100A is carried by a wire and magnetic field at a distance "100 cm" away from the wire is wanted to find, calculations below:

$$B = \frac{4\pi 10^{-7} m \cdot \frac{T}{A} \cdot 100\ A}{2\pi \cdot 1m} \tag{4}$$

When the calculation in (4) is carried out it is found that the generated magnetic field is $B=2\cdot10^{-2}$ μT. When the wire is wound thousands of times, it still cannot reach the order of mT. In addition, the rated current for a conventional conductor cannot resist beyond 100A. Therefore, in order to obtain the magnetic field on the order of T, conductor having super conducting abilities named as "superconductor" is required.

It is approved that every material resists to applied voltage and every material is current-limited material. This is not true for some materials below a certain temperature, actually since 1911. In 1911, Dutch physicist Heike Kamerlingh - Onnes found that when the temperature of the material is below a certain value, named as critical temperature, T_C, the resistance of the material drops suddenly to zero. He found this phenomenon as he worked with mercury, which is a superconductor below 4.2 K [4]. Measurements show that resistivities of the superconductors below their T_c values are less than $4\cdot10^{-25}$ Ω·m. This value is 1017 times smaller than the resistivity of a conventional conductor, copper. In practice, resistivity below critical temperature is assumed to be zero [4].

Today, thousands of superconductors are known including mercury, aluminium, tin, lead, zinc and indium. Interestingly, though copper, silver, gold are excellent conductors they do not show superconducting features.

Table 2. Critical Temperatures for Various Superconductors

Material	**Critical temperature in K**
Zn	0.88
Al	1.19
Hg	4.14
$YBa_2Cu_3O_7$	90
$RbCs_2C_{60}$	33

The super feature of a superconductor is not limited to zero resistance below a certain temperature. In 1933, Meissner and Ochsenfeld tried to measure the magnetic field distribution inside the superconductors. The result they have seen was fascinating [5]. When the magnetic field is applied externally to the superconductor sample when the temperature is higher than the critical temperature, it passes through the sample. However, when a magnetic field is applied if the temperature is below the critical temperature, the sample behaves like a diamagnetic material. This phenomenon is called as Meissner Effect. Meissner Effect is valid up to a certain value of the magnetic field. This magnetic field is named as critical value of magnetic field. After critical value, superconductor sample cannot resist and it must allow the external magnetic field to pass through it.

3. Results and Discussion

Since the 1950s, it has been the main objective to reach the room temperature T_C superconductors for the course of superconductors. Single metal superconductors have not given the required sense of high critical temperature. On the other hand, alloy metals and organic superconductors have had the sense to reach high critical temperature even room-temperature T_C superconductors due to their structural customization abilities although organic materials were used to synthesize insulators at the beginning. Successive developments on organic electronics make a focus shift to high conductivity and superconductivity on high critical temperature [6,7]. It is true that there is a long way for critical temperatures of organic superconductors to reach room temperature. However, thanks to cryogenic liquids, necessary cooling to reach critical temperatures of organic superconductors is possible. By usage of air liquefiers like Stirling Cryocoolers, powerful air compressors, cryogenic liquids cooling down to critical temperatures can be produced [8]. Superconductivity of organic superconductors depend on applied pressure and the process how organic material is annealed. Although vast majority of the organic compound superconductors have critical temperature less than 10K, there is always to have a hope to reach room temperature superconductors [6,9].

Organic superconductors are made up of carbon and hydrogen, as an addition selenium and a second material which is organic or inorganic. organic metals whose structure is crystalline are able to conduct electricity and as temperature decreases low temperature resistivities of such metals decrease, too [9]. The reason why there is an intense interest in organic metals is that thanks to its customizable chemical structure they form an uniquely flexible system for the study of superconductivity, magnetism and other effects. Organic metals have many interesting features like quasi-two- dimensional band structure, ability of antiferromagnetism, ability of insulating and superconductivity [11]. It is rather possible to observe a lot details of electronic energy levels of these materials by utilizing proper techniques [9,11]. As a whole, organic materials are fascinating due to its exotic phases measured at potentially accessible magnetic fields and temperatures (B ~ 50, 100 T) [11]. As stated in [13] current status is rather exciting and organic materials are exciting about high-temperature superconductors. In 2014, hydrogen sulphide under high pressure was experimented and found to explore superconductivity at $T_C = 200$ K, which is a record value [13].

Organic superconductors have caught attention thanks to discovery of metallic behaviour in the charge transfer - complex (CT) composed of tetrathiafulvalene (TTF) and tetracyanoquinodimethane (TCNQ). It is worth to mention that charge transference compounds formed by reacting an electron donor and an acceptor molecule could form metallic materials with considerably high electrical conductivities. This discovery stimulated many experimental studies on new donor compounds [6, 12]. Later, the superconductivity in the CT salts of tetramethyltetraselenafulvalene (TMTSF) and bis(ethlylenedithio) tetrathiafulvalene (BEDT-TTF or ET) was discovered [14]. Lastly, in the last studies, the synthesis of new TTF -based organic materials has been synthesized for metallic and organic superconductors [10,11, 15, 16].

4. Conclusion

Technological developments can be given as one way of modernization. Modern life demands some requirements from technology. As these requirements are increased, technological breakdowns occur. Contemporary technologies become conventional technologies and advanced technologies satisfy the requirements brought by modern life. High current capacity at room temperature for current carrying systems can be given as an example for these requirements. Higher current capacity demands from electrical systems force these systems to replace superconductors. The technology which opens door to room-temperature superconductors sparking the revolution which can be seen in every electrical equipment is nothing but organic electronic systems. Beside of higher current capacity, when medical imaging systems, motors, magnets, futuristic projects like superconductive energy storage systems, magnetic levitation trains, energy transfer systems without power loss are considered, huge e-waste is inevitable, which is brought by modern life, too. The only thing to eliminate this e-waste is to spread the usage of organic compounds. Thanks to organic compounds, nature is polluted less and organic structures so-called "e-wastes" join nature smoothly without dirtying the nature. To conclude, in order to maintain the nature towards drastic demands brought by modern life the usage of organic superconductors should be spread.

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